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OPERATING INSTRUCTIONS

for

TYPE 561-D VACUUM-TUBE BRIDGE

INSTRUMENT SHOP

SER. #885

GENERAL RADIO COMPANY

CAMBRIDGE 39 MASSACHUSETTS

NEW YORK CHICAGO LOS ANGELES

U. S. A.

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for

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Form 307-I
July 1953

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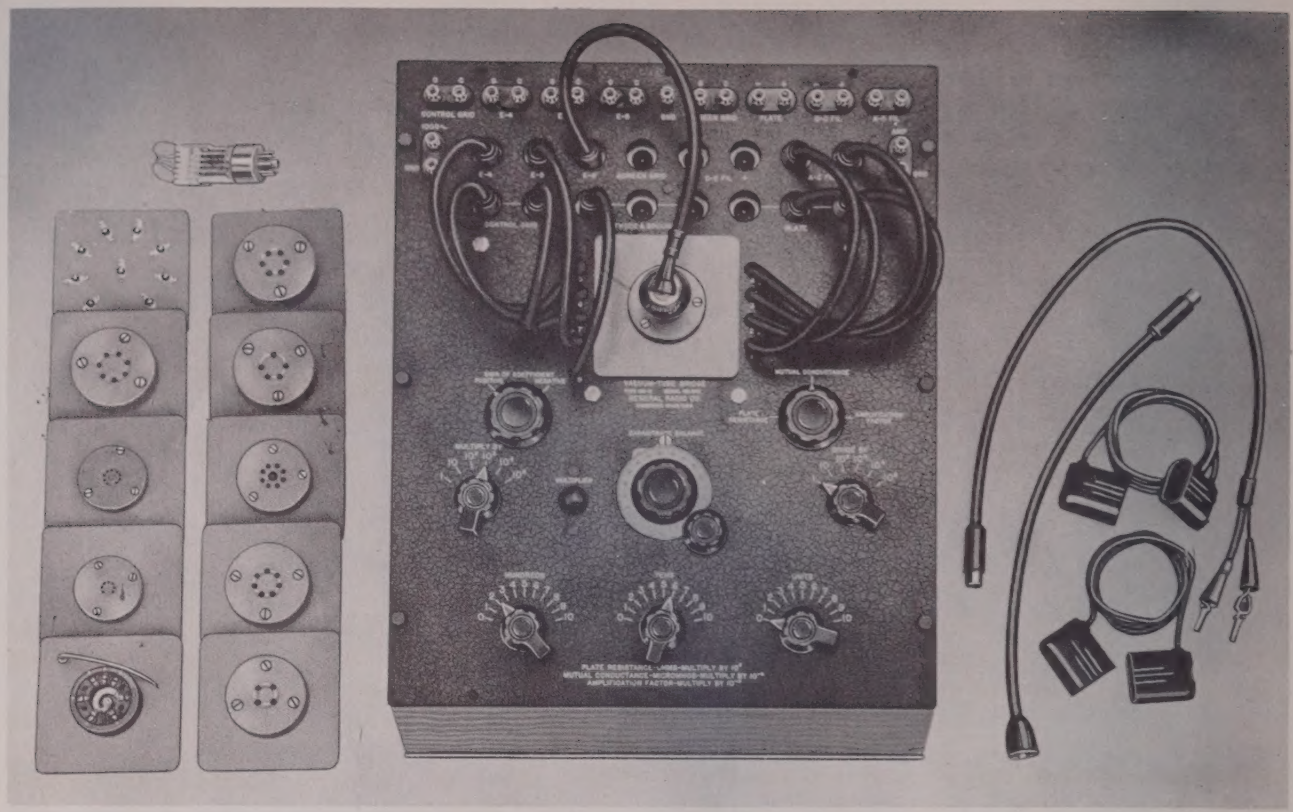


SPECIFICATIONS

Range: Amplification factor (μ); 0.001 to 10,000.

Dynamic internal plate resistance (r_p); 50 ohms to 20 megohms.

Transconductance (g_m); 0.02 to 50,000 micromhos.

Under proper conditions, the above ranges can be exceeded. The various parameters can also be measured with respect to various elements, such as screen grids, etc. Negative as well as positive values can be measured.

Accuracy: Within ±2% for resistances (r_p switch position) from 1000 to 1,000,000 ohms. At lower and higher values the error increases slightly.

The expression $\mu = r_p g_m$ will check to ±2% when the quantities are all measured by the bridge, and when r_p is between 1000 and 1,000,000 ohms.

Tube Mounting: Adaptors are provided as follows: 4-pin, 5-pin, 6-pin, small 7-pin, large 7-pin, octal, locking in, miniature button 7-pin, miniature button 9-pin (noval), acorn (5- and 7-pin), flat-press sub-miniature up to 7 wires, and 8-wire sub-minar. For short-lead sub-miniature tubes and for flat-press transistors, sockets are supplied which can be mounted on one of the adaptors. Thus all standard commercial receiving tubes can be measured. In addition, a Universal adaptor, with nine soldering lugs, is provided so that other transistors, unmounted tubes, or tubes with non-standard bases, can be measured conveniently. The panel jack plate and the adaptors are made of low-loss material, usually yellow phenolic, reducing to a minimum the shunting effect of dielectric losses on the dynamic resistance being measured.

Current and Voltage Ratings: The circuits have large enough current-carrying capacity and sufficient insulation so that low-power transmitting tubes may be tested in addition to receiving tubes and transistors. Maximum allowable plate current is 150 ma and maximum plate voltage is 1500 volts.

Electrode Voltage Supply: Batteries or suitable power supplies are necessary for providing the various voltages required by the device under test.

Bridge Source: A source of 1000 cycles is required. The Type 1214-A Oscillator, Type 813-A Audio Oscillator or the Type 723-A Vacuum-Tube Fork is suitable for this purpose.

Null Indicator: The Type 1212-A Unit Null Detector with the Type 1951-A Filter or the Type 1231-B Amplifier with the Type 1231-P2 Filter and a pair of sensitive head telephones are recommended.

Accessories Supplied: Adaptors as listed above, all necessary plug-in leads, and shielded patch cords for connecting generator and detector.

Mounting: The instrument is mounted in a walnut cabinet. A wooden storage case is provided for the adaptors and leads. Storage space is provided for a spare Universal adaptor, on which any type of socket can be permanently mounted.

Dimensions: (Length) 18 3/8 x (width) 15 3/4 x (height) 12 inches.

Net Weight: 60 pounds.

Operating Instructions

for

Type 561-D Vacuum-Tube Bridge

1.0 PURPOSE

The Type 561-D Vacuum-Tube Bridge makes possible the measurement of the low frequency dynamic coefficients of vacuum tubes and transistors over very wide ranges of values, and under a wide variety of operating conditions. The circuits used are such that independent, direct-reading measurements of forward and reverse voltage-amplification factor, resistance, and transconductance can be made quickly and easily. Interelectrode and other stray capacitances are balanced out in such a manner that awkward correction factors, common to most vacuum-tube bridge circuits, are unnecessary.

The procedure in making measurements is simple and straightforward, and the three coefficients, voltage-amplification factor, "plate" resistance, and transconductance are obtained by following exactly the same procedure. A three position switch is turned to whichever quantity is desired, multiplier switches are set at the appropriate value, and balance is obtained by adjusting a three-decade attenuator and a variable condenser. At balance the decades read directly, to three significant figures, the quantity being measured.

The circuits have large enough current-carrying capacity and sufficient insulation so that low-power transmitting tubes may be tested in addition to receiving tubes and transistors.

The measuring circuits and the control portion of the bridge are completely separated, connection between the two being made by a flexible concentric plug-and-jack arrangement. This makes it possible to measure, conveniently grid circuit parameters, or in the case of multi-element tubes and of transistors, parameters referred to any pair of electrodes.

Negative values of the coefficients can be measured directly as readily as positive values, except that in some cases precautions must be taken to prevent dynatron oscillations.

2.0 GENERAL CONSIDERATIONS

A vacuum-tube, a transistor, an attenuator, or an amplifier can each be considered as a 4-terminal transducer as in Figure 1. Two equations can express the input and output currents in terms of applied voltages and four admittance parameters. At the low frequency used for the bridge (1000 cycles), the real (conductance) component only of the admittance is significant. The four conductances are sufficient to define completely the characteristics of the transducer.

$$i_1 = g_{11}\, v_1 + g_{12}\, v_2$$

$$i_2 = g_{22}\, v_2 + g_{21}\, v_1$$

g_{11} and g_{21} are the input conductance and the forward transconductance obtained with the output terminals shorted. g_{22} and g_{12} are the output conductance and the reverse transfer (feedback) conductance with the input terminals shorted. The Type 561-D Bridge indicates (as resistance) the reciprocal of the input conductance g_{11} and of the output conductance g_{22}; it indicates directly as a transconductance the forward transconductance g_{21} (g_m of a vacuum tube) and the reverse transconductance g_{12}. In usual vacuum-tube measure-

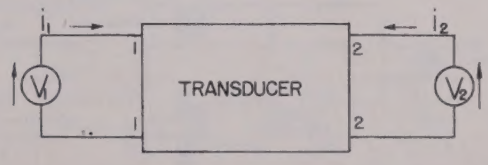


Figure 1. The bridge sees a transducer, regardless of whether it is a tube, transistor, amplifier or attenuator.

ments, only the reciprocal of g_{22} (r_p, the plate resistance) and the forward transconductance, g_{21} (g_m) are important. In transistor measurements, the four parameters are important.

The various amplification factors can be derived from the conductance values, as follows:

Forward current-amplification factor, $\alpha_{21} = -\frac{g_{21}}{g_{11}}$

Reverse current-amplification factor, $\alpha_{12} = -\frac{g_{12}}{g_{22}}$

Forward voltage-amplification factor, $\mu_{21} = -\frac{g_{21}}{g_{22}}$

Reverse voltage-amplification factor, $\mu_{12} = -\frac{g_{12}}{g_{11}}$

Forward power-amplification factor, $\phi_{21} = \frac{(g_{21})^2}{4 g_{11} g_{22}}$

Reverse power-amplification factor, $\phi_{12} = \frac{(g_{12})^2}{4 g_{11} g_{22}}$

The Type 561-D Bridge can measure directly the voltage-amplification factor (μ). The current-amplification factor is of major interest in transistor applications; the voltage-amplification factor is important in vacuum-tube applications.

The input and output resistance, the transconductances and the amplification factors are the dynamic coefficients of the transducer.

3.0 PRINCIPLES OF OPERATION

The dynamic coefficients are defined in terms of small incremental voltages or currents in the various electrode circuits. Voltage-amplification factor, for example, is a measure of the change in output voltage required to balance out the effect on the output current of a small change in input voltage.

Although the coefficients are defined in terms of small d-c increments of voltage and current, (or more strictly speaking, as partial derivatives of the operating function), measurements may usually be more conveniently obtained in terms of small alternating voltages superimposed on the steady electrode values. When a-c methods are employed, however, precautions must be taken to insure that the test voltages are accurately in phase, and that stray reactances such as those of the inter-electrode capacities of a tube do not introduce serious error. In the design of the Type 561-D Vacuum-Tube Bridge particular attention was paid to eliminating these potential sources of error.

With the circuits employed, each of the coefficients is obtained in terms of the ratio of two alternating test voltages. A third voltage is employed in the capacitance-balancing circuit, but its value does not enter into the results.

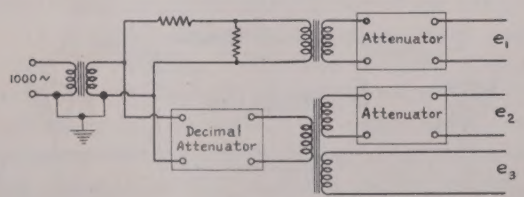


Figure 2. Simplified Diagram of Source of Test Voltages.

Figure 2 shows the circuit for the production of the test voltages. It will be seen first of all that the three voltages are obtained from separate transformer windings so that they are insulated from one another for direct current. This makes it possible to connect the supplies for the electrode voltages to ground potential where they will not increase the stray capacitances.

In order that all three voltages shall be in phase and that the ratio e_2/e_1 shall be accurately determinable, the transformers employed are identical with the exception of the capacitance-balancing winding, which draws negligible current. The respective primary circuits are designed so that both transformers work out of the same resistance. The secondaries work into identical attenuators.

The input attenuator to the second transformer has three dials, the setting of which determines to three significant figures the voltage ratio e_2/e_1 and consequently the factor being measured. The attenuators on the secondary side introduce as multiplying factors various powers of 10, and consequently determine the position of the decimal point in the result.

In Figure 3 are shown simplified circuit diagrams indicating the manner in which the test voltages are introduced into the electrode circuits for the measurement of the coefficients.

In all cases it will be seen that the voltage e_3 in series with a variable condenser is connected directly across the telephones, resulting in quadrature current in opposition to that flowing through the tube or transistor capacitances. If the rest of the measuring circuit is properly designed, this method of obtaining the quadrature balance results in the capacitances having negligible

effect on the measured result for extremely wide ranges of the coefficients.

At the center of each diagram is given the equivalent circuit, omitting the capacitance-balancing system.

In the circuit for the measurement of voltage-amplification factor the alternating voltage e_1 in the input circuit results in an equivalent voltage μe_1 in series with the output resistance. Balance is obtained when the voltage e_2 is equal and opposite to this equivalent voltage. Then

$$\mu e_1 = e_2$$

or

$$\mu = e_2/e_1$$

In measuring transconductance we wish to determine the alternating output current flowing as a result of a small voltage introduced into the input circuit, under the condition that there shall be no alternating voltage at the output. The diagram shows that the condition is satisfied, because the telephones are connected directly at the output, and at balance there is no voltage across the telephones.

The equivalent circuit shows that the measurement is made by what is essentially a current balance rather than a voltage balance. The output current is balanced against the current flowing through a standard resistance R_s. When the currents i_1 and i_2 are equal there is no voltage across the telephones. Consequently,

$$i_1 = \mu e_1/r$$

$$i_2 = e_2/R_s$$

and the balance condition becomes

$$\mu e_1/r = e_2/R_s$$

or

$$\frac{\mu}{r} = g = \frac{e_2}{e_1}\frac{1}{R_s}$$

The remaining diagram shows the circuit for the measurement of output resistance. The operation is exactly the same as that of the circuit for obtaining transconductance. The only change is that the test voltage is in the output circuit instead of in the input circuit, and that since a resistance instead of a conductance is being measured, the voltages e_2 and e_1 are interchanged. As before, the balance condition is

$$e_2/r = e_1/R_s$$

or

$$r = R_s e_2/e_1$$

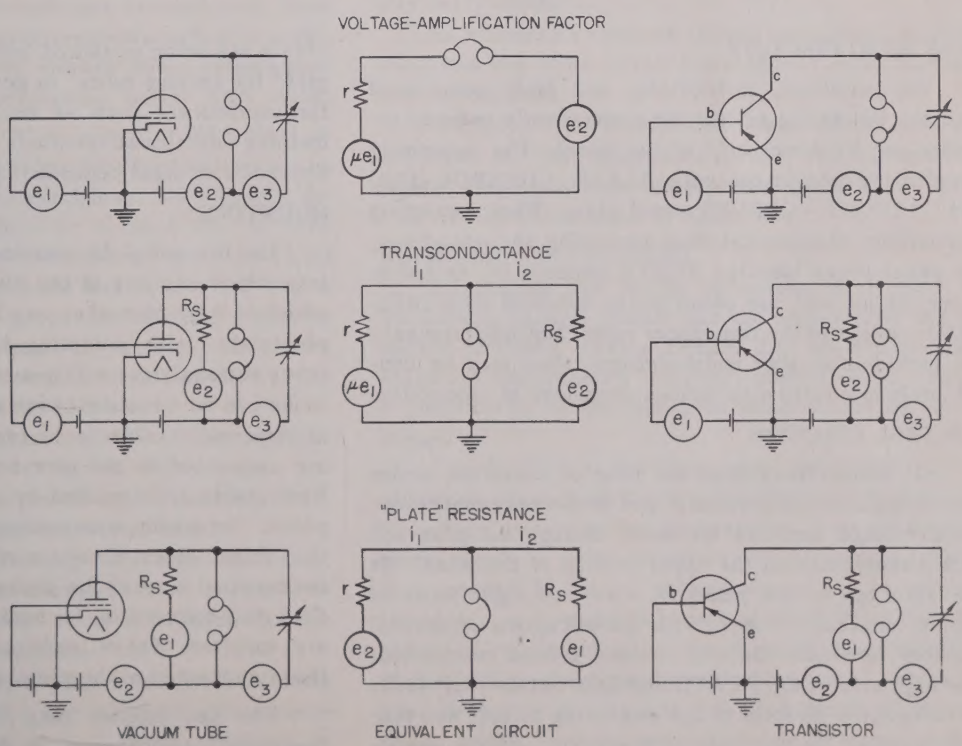


Figure 3. Simplified Diagrams of the Measuring Circuits.

When measuring vacuum-tube coefficients, usually the forward coefficients only are of interest. The "r" and "g" in the above equations are then, r_p, the plate resistance and g_m, the transconductance.

In the circuits for both voltage-amplification factor and transconductance it is evidently necessary that the resistance of the voltage source in the input circuit be low enough so that e_1 is actually applied to the input without change of magnitude or phase. This is the usual condition when measuring vacuum tubes since the input circuit is the grid circuit and its resistance is very high. When measuring transistors, however, the input-circuit resistance can be low and a correction may be necessary. This correction rarely exceeds two percent and usually is negligible. See "CORRECTION DUE TO SOURCE RESISTANCE" on page 9.

Other conditions which must be satisfied in the measuring equipment are that the resistance of both e_1 and e_2 be small in comparison with the standard resistance, and that the resistance of e_2 be small compared with the lowest electrode resistance to be measured.

The conditions are usually satisfied. Even when measuring low-resistance transistors, the error in indicated resistance is less than 1% if 1Ω is subtracted from the measured value. See "CORRECTION DUE TO SOURCE RESISTANCE" on page 9.

It will of course be understood that the discussion given in this section applies not only to the measurement of the usual three coefficients of a triode but also to the measurement of all parameters referred to any pair of electrode circuits in transistors and in the more complex types of electron tubes. In the measurement of the usual grid-circuit coefficients, for example, it is necessary only to interchange grid and plate connections in the diagrams given. Negative amplification factor and transconductance are commonly observed in this case, and are measured by reversing the phase of e_1 by means of the switch provided.

An effort has been made to refine the design of the measuring circuits to such an extent that no changes of operating technique will be required even over the large ranges of coefficient values encountered in the various electrode circuits of vacuum tubes and of transistors.

A more complete analysis of the circuits employed in the bridge will be found in the paper "Dynamic Measurement of Electron Tube Coefficients" by W. N. Tuttle, Proceedings of the Institute of Radio Engineers 21, pp. 844-857, June, 1933.

4.0 CONSTRUCTIONAL DETAILS

MEASURING CIRCUITS

The switches, multipliers, and dials associated with the measuring circuit are conveniently grouped together on the lower half of the panel. The measuring circuits are brought out to the PLATE, CONTROL GRID and CATHODE – GROUND panel plugs. When measuring a transistor, or in general when measuring any transducer, the panel plugs labelled PLATE connect to the transducer output and the panel plugs labelled CONTROL GRID connect to the transducer input. Multiple terminals are provided so that multi-element tubes may be conveniently measured with various groupings of electrodes.

CONTROL CIRCUITS

All connections from the tube or transistor under test to the measuring circuits and to the necessary electrode voltage supplies are made through the plug and jack arrangement on the upper portion of the panel. At the very top of the panel is a row of eight pairs of supply terminals. These, with the exception of the AC filament terminals, have a common ground connection. The high side of the PLATE and CONTROL GRID jacks are connected directly to the measuring circuit and provide voltage for the pair of electrodes whose coefficients are being measured (normally "plate" and "control grid" for vacuum tubes, in general "output" and "input" for transducers such as transistors). Each of the remaining ungrounded terminals is connected to one of the upper row of eight concentric panel plugs.

MOUNTING

On the panel is mounted a nine-point jack base, into which any one of ten plug plates, each carrying a standard type of socket may be plugged. A "universal" plug-plate, with soldering lugs, is provided so that tubes or transistors with non-standard bases or unmounted tubes can be measured. Nine shielded cables terminated in concentric cable jacks protrude from the panel and are connected to the nine terminals of the jack base. Each cable is identified by a number engraved on the panel. The wiring arrangement of the plug bases is such that this number always corresponds to the number of the terminal on the tube socket to which it is connected. Grid lead connectors, for both large and small grid caps, are supplied. These leads are shielded and similar to those connected to the plug base.

The ten adapter plug plates (in addition to the "universal" adapter) provide for all tubes using 4-prong,

5-prong, 6-prong, small 7-prong, medium 7-prong, loctal, octal, noval, miniature 7-prong, and acorn (5-prong and 7-prong) sockets.

In addition to the plug plates, two adapters are supplied for measuring the long-lead sub-minar and flat-press sub-miniature tubes. These adapters plug into the octal plug plate. For sub-miniature tubes with short wire leads and for some transistors, separate 5-pin, 6-pin and 7-pin flat-press and 8-pin sub-minar sockets are supplied. They can be wired directly to the "universal" plug plate.

These sockets as well as the adapters, plug plates and jack base are moulded of low-loss yellow bakelite. Dielectric losses are thus kept at a minimum and the usefulness of the bridge for the measurement of high-impedance tubes or transistors is enhanced.

ELECTRODE VOLTAGE CONNECTIONS

The various electrode voltages are connected to the several pairs of terminals at the top of the bridge. One side of all voltage sources (except the a-c filament terminals) is at ground potential. This arrangement prevents stray capacitance from supplies to ground from entering into the measurement - an important consideration with high-impedance devices.

VOLTAGE AND CURRENT RATING

The Type 561-D Bridge has a maximum d-c "plate" voltage rating of 1500 volts, and a maximum "plate" current rating of 150 milliamperes.

5.0 OPERATING INSTRUCTIONS

AUXILIARY EQUIPMENT

In addition to supplies for the various electrode voltages, the necessaty auxiliary equipment consists of a source of 1000-cycle voltage, an amplifier, and a pair of head telephones or loud-speaker.

1000-cps Voltage Source - The frequency of the test voltage should be reasonably close to the indicated value, say between 970 and 1030 cycles, in view of the fact that a tuned output transformer is employed. From 5 to 30 volts across the input terminals will give sufficient sensitivity, the lower voltage being satisfactory except when measuring resistance below 2000 ohms.

The input impedance of the bridge is 2000 ohms so that either a high- or low-impedance voltage source may be employed without serious mismatch loss. For example, the loss is less than 1.5 decibels for either a 500- or 5000-ohm source. The General Radio Company Type 1214-A Unit Oscillator provides an adequate and convenient source.

Amplifier - It is not necessary that the amplifier employed with the bridge should be extremely sensitive, although it will usually be found desirable to have available a voltage gain of at least 40.

The most important characteristic of the amplifier is that it shall be free from outside disturbances, especially pickup, either electrostatic or electromagnetic, from the oscillator supplying the test voltage.

The output circuit of the bridge is of high impedance, so that no input transformer should be used to couple to the first tube of the amplifier. There is no direct-current path between the output terminals.

The General Radio Type 1212-A Unit Null Detector is generally satisfactory for use with the vacuum-tube bridge. It has ample gain, is completely shielded, is self-contained and indicates the balance condition on a large panel meter. When measuring noisy tubes or transistors, greater selectivity may be desirable and can be provided by inserting a Type 1951-A Filter between the bridge and the null detector. Since the ear can distinguish a signal in the presence of considerable noise, headphones at the terminals in the rear of the Type 1212-A Detector will permit measurements in spite of an unusually noisy condition.

An alternative detector is the Type 1231-B Amplifier used with the Type 1231-P2 or 1231-P5 Filter and with head telephones.

The Type 1231-B Amplifier is also useful as a preamplifier for the Type 1212-A Unit Null Detector if greater sensitivity than that provided by the Type 1212-A Unit Null Detector alone is desired.

EXTERNAL CONNECTIONS

To prepare the bridge for operation, connect the 1000-cycle voltage source and the amplifier to the terminals provided, making certain that the low potential sides are connected to the posts marked GND. Connect a ground wire to the indicated point at the top of the bridge.

For the bias at the control-grid terminals it is desirable to use a fresh battery in order to keep the input-circuit resistance as low as possible. If an a-c rectifier power supply or a potentiometer voltage control is used, or in general if the d-c voltage source has appreciable impedance, a by-pass capacitor of about 40 microfarads should be connected at the control-grid-voltage terminals of the bridge when measuring vacuum tubes, and a by-pass capacitor of at least 750 microfarads when measuring relatively low input-resistance devices such as

transistors. The d-c current through the capacitor may be appreciable and should be considered when measuring the d-c current to the electrode. It is necessary that the control-grid and the plate supplies be entirely separate, especially for high amplification factor measurements as any appreciable coupling between the two circuits will introduce error into the measurement.

Either batteries or well-filtered, rectified a-c may be used for the "plate" and "screen" supplies. Except where good batteries are used without controlling resistances, all electrode voltages should be separately by-passed. If the output resistance of the device being measured is low, as it can be for transistors, especially when measuring the reverse coefficients, the by-pass capacitor should be at least 750 microfarads. The d-c current through the capacitor may be appreciable and should be considered when measuring the d-c current to the electrode. One method is to connect the ammeter between the capacitor and the bridge terminal taking care to short out the ammeter when obtaining a bridge balance to avoid pickup errors.

When using large capacitors at the CONTROL-GRID and PLATE bridge terminals, the circuit time constant may be annoyingly long if the battery potentiometer or power-supply resistance is too large. As a consequence, an appreciable time will be required to reestablish equilibrium conditions each time the electrode voltage is changed. The obvious solution is the use of low-resistance voltage controls; for example, a 5000-ohm voltage divider is satisfactory when the by-pass capacitor is 750 microfarads.

The voltages at the tube or transistor electrodes are essentially the same as the voltages at the bridge terminals. If the output current is quite large, however, the d-c voltage drops across the resistance of the primary of the output transformer (75 ohms) and across the "DIVIDE BY" attenuator (5 ohms at 1, 9 ohms at 10 and 1 ohm at 10^2, 10^3, 10^4, and 10^5) may be significant. Similarly, if the electrode voltage is small as it sometimes is when measuring transistors, the d-c voltage drops, though small, may be relatively important. The supply voltage may be corrected for the drops, if necessary, or a voltmeter may be connected between a free "PLATE" concentric jack and ground, but the meter must be disconnected when balancing the bridge to avoid pickup errors.

TUBE CONNECTIONS

With the proper plug plate inserted in the jack base, insert the tube in the socket. Using a chart of the base connections of the tube as a guide, connect the tube to the voltage supplies and the measuring circuits by means of the concentric jack connectors. The panel plugs are clearly identified on the panel and it is merely necessary to connect the corresponding leads.

CONNECTION OF TRANSISTORS AND OF TUBES IN EXTERNAL SOCKETS

Measurements can easily be made on transistors or on unmounted tubes or on tubes with other than the standard receiving-tube bases. For this purpose a universal plug plate carrying 9 soldering lugs is provided to which the electrodes can be connected. The device may then be connected into circuit in exactly the same manner as though it were mounted directly on a plug plate socket in the usual way. Many transistors plug into a 5-pin flat-press sub-miniature socket. Such a socket is supplied as an accessory to the bridge. This transistor socket as well as transistor sockets for other base connections can be mounted on the same 9-pin UNIVERSAL adaptor. Since there are usually three electrodes per transistor, three different transistor sockets can thus be mounted on the adaptor.

Since the power supplies for the transistor can be small batteries, entire multi-stage amplifiers with their supplies can be mounted on the UNIVERSAL adaptor to obtain the amplifier characteristics under normal load conditions.

One precaution should be noted, if the device under measurement is located some distance from the plug plate. The lead connecting through to the PLATE terminal of the measuring circuit must be shielded with the shield connected to the internal PLATE lead shielding of the bridge. The special lead with the two clip terminals supplied as an accessory can be inserted into one of the unused PLATE panel plugs to make the shield connection. The circuit is such that when the shield is connected in this manner not only is external coupling to the plate lead prevented, but losses in the insulation of the shielded wire do not affect the measurements. It should be noted that the shield terminal is at B+ potential.

MEASUREMENT ON LOW-POWER TRANSMITTING TUBES

Small transmitting tubes can be measured in an external socket as described above. The plate voltage should be disconnected when the position of the coefficient switch is changed in order to avoid the possibility of arcing between the switch points. It is important that neither the current-carrying capacity nor the voltage rating of the bridge, 150 milliamperes and 1500 volts, respectively, should be exceeded.

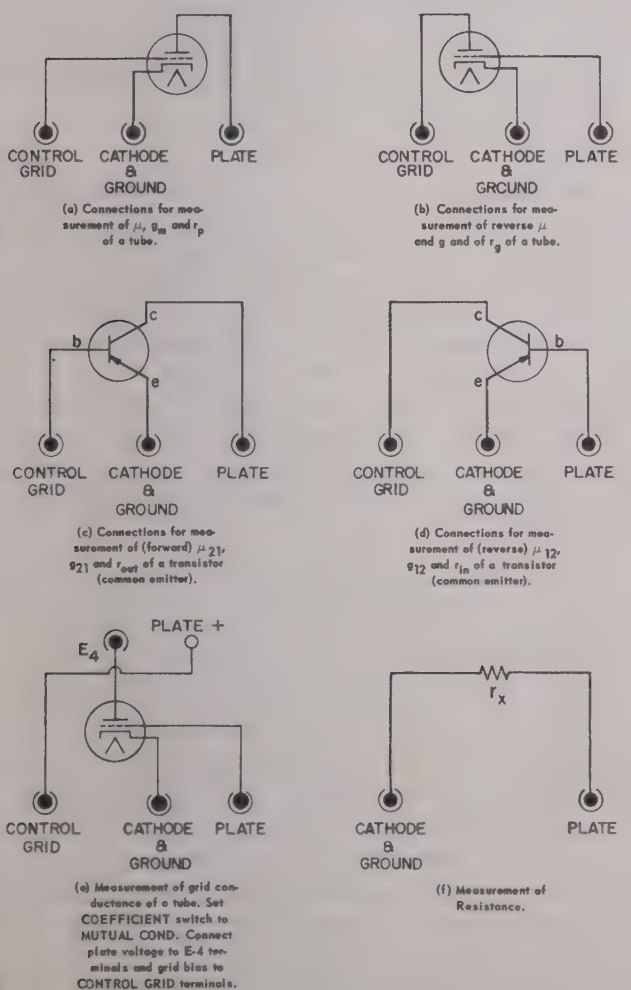
MEASUREMENT OF AMPLIFICATION FACTOR, MUTUAL CONDUCTANCE, AND OUTPUT RESISTANCE

The method of balancing the Type 561-D Bridge is exactly the same for all three coefficients and for both

forward and reverse connections. Set the coefficient switch to the quantity which it is desired to measure, and turn the MULTIPLY BY and DIVIDE BY switches to the proper settings determined by the magnitude of the coefficient. Table I will be found helpful in making this adjustment. Balance the bridge by varying the three decimal attenuator controls at the bottom of the panel and the CAPACITANCE BALANCE dial. Always have either the MULTIPLY BY or DIVIDE BY switch set at the position "1". This gives maximum sensitivity and accuracy. The SIGN OF COEFFICIENT switch is usually at POSITIVE for vacuum-tube measurements. It sometimes is at NEGATIVE for the measurements of some transistor coefficients.

FIGURE 4.

CONNECTIONS FOR TYPICAL MEASUREMENTS


CONTROL GRID
CATHODE & GROUND
PLATE
(a) Connections for measurement of μ, g_m and r_p of a tube.
CONTROL GRID
CATHODE & GRCUND
PLATE
(b) Connections for measurement of reverse μ and g and of r_g of a tube.
c
b
e
CONTROL GRID
CATHODE & GROUND
PLATE
(c) Connections for measurement of (forward) μ_{21}, g_{21} and r_{out} of a transistor (common emitter).
(d) Connections for measurement of (reverse) μ_{12}, g_{12} and r_{in} of a transistor (common emitter).
PLATE +
E_4
(e) Measurement of grid conductance of a tube. Set COEFFICIENT switch to MUTUAL COND. Connect plate voltage to E-4 terminals and grid bias to CONTROL GRID terminals.
r_x
(f) Measurement of Resistance.

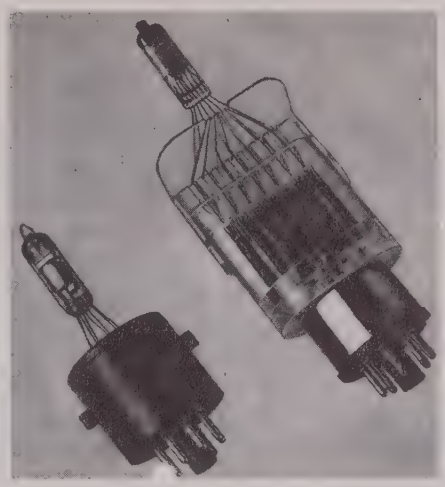


Figure 5. Adaptors for sub-miniature tubes. Flat-press types with up to 7 leads are tested in the Type 561-415-2 Adaptor with a comb-like structure for selecting and guiding the leads into the spring contacts. Eight-wire subminar tubes are tested in the round Type SOA-3 Adaptor, which has provision for locking the leads into the socket. Both types plug into the standard octal adaptor.

When a null indication is obtained, the three decimal attenuator dials at the bottom of the panel read directly the value of the coefficient to three significant figures. The factor associated with the particular coefficient (see bottom of panel) and the setting of the MULTIPLY BY or DIVIDE BY attenuators must be taken into account when determining the location of the decimal point. Table I shows the ranges of the coefficients for various attenuator settings.

Balance should be obtained, if possible, with the capacitance MULTIPLIER pushed in, as the adjustment is less critical in this position. It is only when the currents through the electrode capacitances are relatively large that it will be found necessary to pull out the multiplier switch.

If excessive test voltage is applied, results will not be satisfactory. In this case the harmonics generated will usually be noticeable and will indicate that the voltage applied to the bridge should be reduced. In any case, the voltage applied should be sufficiently small so that further reductions do not appreciably change the measured coefficient values.

A check on the precision of the balances can be obtained by measuring all three parameters independently and substituting the values into the equation $\mu = rg$. The equation should check within 2%, if the device has reached stable operating conditions.

TABLE I

COEFFICIENT RANGES OF TYPE 561-D VACUUM-TUBE BRIDGE

Voltage Amplification Factor (Numeric)	Setting of Attenuators: Multiply By	Setting of Attenuators: Divide By
0.0001 - 0.001	1	10^3
0.001 - 0.01	1	10^2
0.01 - 0.1	1	10
0.1 - 1	1	1
1 - 10	10	1
10 - 100	10^2	1
100 - 1000	10^3	1
1000 - 10000	10^4	1

Mutual Conductance (Micromhos)	Setting of Attenuators: Multiply By	Setting of Attenuators: Divide By
0.001 - 0.01	1	10^3
0.01 - 0.1	1	10^2
0.1 - 1	1	10
1 - 10	1	1
10 - 100	10	1
100 - 1000	10^2	1
1000 - 10000	10^3	1
10000 - 100000	10^4	1

Plate Resistance (Ohms)	Setting of Attenuators: Multiply By	Setting of Attenuators: Divide By
10 - 100	1	10^3
100 - 1000	1	10^2
1000 - 10000	1	10
10000 - 100000	1	1
10^5 - 10^6	10	1
10^6 - 10^7	10^2	1
10^7 - 10^8	10^3	1

MEASUREMENT OF INPUT-CIRCUIT COEFFICIENTS

The input resistance, inverse voltage-amplification factor, and inverse transfer conductance of a tube or of a transistor are measured by interchanging the connections as indicated in Figure 4. When the measuring circuit connections are interchanged, the supply voltages must also be interchanged. The measurement is made in the conventional manner and the ranges of the coefficients shown in Table I apply equally well to the input-circuit coefficients. Negative values are usually encountered, however, and it is necessary in these cases to throw the SIGN OF COEFFICIENT switch accordingly. It is usually necessary to keep the input voltage to the bridge small when measuring the input-circuit coefficients.

To measure grid conductance of a tube directly, instead of its reciprocal, grid resistance, make the cross connections as illustrated in Figure 4 (e). Set the coefficient switch to MUTUAL CONDUCTANCE and proceed in the usual manner. The same factors are used to locate the decimal point as in the case of mutual conductance, and the ranges are tabulated in Table I.

MEASUREMENT OF COEFFICIENTS REFERRED TO ANY PAIR OF ELECTRODES

In the connections described for the measurement of input-circuit coefficients it will be observed that the "grid" and "plate" circuits are merely interchanged in their connections to the measuring circuits. In a similar manner any electrode can replace the "plate" and any other electrode the "grid".

MEASUREMENT OF NEGATIVE ELECTRODE RESISTANCE

Dynatron oscillations will occur when the negative plate resistance of a tube is lower than the impedance of the output transformer. Oscillation can always be prevented by connecting a resistance lower than the negative plate resistance across the output transformer. This connection (between the PLATE terminal and plate shield may be made through one of the PLATE panel plugs by means of the special lead supplied.

No correction need be applied for the shunt resistance employed, as the measurement of none of the three coefficients is affected. A slight reduction in sensitivity will generally be observed, however.

MEASUREMENT OF RESISTANCE

When the coefficient switch is thrown to PLATE RESISTANCE the Type 561-D Vacuum-Tube Bridge measures the resistance at 1000 cycles between the PLATE and CATHODE – GROUND terminals of the measuring circuit. An external resistance can be conveniently measured by connecting it between a pair of terminals of the jack base, with the corresponding connector cables connected to the PLATE and CATHODE – GROUND plugs. No batteries are needed and the PLATE battery terminals should be short-circuited to maintain circuit continuity, when resistance measurements are being made.

The bridge is balanced for external resistance in exactly the same manner as for "plate" resistance, the multiplying factors for resistance values being the same as for "plate" resistance, given in Table I.

The bridge is sufficiently sensitive that losses in many insulating materials may readily be measured. It should be noted that the result is the equivalent parallel resistance, the parallel capacitance being balanced out.

TRANSISTOR COMMON ELECTRODE

The vacuum tube is usually operated with grounded cathode but it can be connected with grounded grid or with grounded plate (cathode follower). Similarly the transistor can be connected with grounded emitter, grounded base, or grounded collector. The transistor can be measured for any one of these connections on the

bridge. Moreover, if the coefficients have been determined for one circuit arrangement, the coefficients for the other circuit arrangements can be computed from the simple equations of Table III. See also page 12. For some transistors, the input and output resistances with the common emitter connections are higher than the corresponding resistances with common base or common collector. Under these circumstances, there is an advantage to using the common emitter connection since corrections due to source resistance (see below) are more likely to be negligible.

CORRECTION FOR DIELECTRIC LOSSES AND LEAKAGE

When high values of either dynamic electrode resistance or external resistance are being measured it is necessary to consider the errors resulting from losses in the tube base, in the sockets, and in insulating material in certain parts of the bridge. Such a-c losses are usually considerably greater than the d-c leakage. The losses in the transistor base can not be separated out by the method outlined below but all other losses including those in the transistor socket can be corrected for.

All these losses, together with the d-c leakage resistance are equivalent to a single resistance, R_L, connected between the "plate" and ground. The measured output resistance r' is therefore the parallel resistance of R_L and the actual output resistance (r).

The resistance R_L of the losses can readily be measured separately by making the "plate" resistance measurement as usual, with all connections made, but with the filament unlighted or with the transistor out of its socket. In making this test on a tube, it should have been operating for some time previously with normal electrode voltages and with the filament lighted in order that the base may be at the usual operating temperature.

R_L, exclusive of losses in the tube base or transistor socket is normally in excess of 500 MΩ, but the losses in the base and socket may lower this value to a point where it is desirable to correct for it when measuring resistances of one megohm or greater.

When measuring the effective parallel resistance of external resistors or dielectrics more accurate results will be obtained if correction is made for the bridge losses in all cases where the open circuit reading is less than 100 times the resistance being measured.

The correction is readily made as follows. Let us call r' the measured resistance, R_L the resistance measured with the filament turned off or the transistor or external resistor disconnected and r the true value of resistance. Then

$$r = r' \left(\frac{R_L}{R_L - r'} \right)$$

It can readily be shown that the measured amplification factor is less than the true value by the same factor as the output resistance. Hence

$$\mu = \mu' \left(\frac{R_L}{R_L - r'} \right)$$

where μ' is the directly measured value of voltage amplification factor, and μ is the true value.

The transconductance measurement is not affected by the leakage resistance.

TRANSISTOR MEASUREMENTS

There are two general types of transistors classified according to the nature of the boundary between the N (negative) and P (positive) regions of the semi-conductor: the junction type where the boundaries are relatively large areas and the point-contact type where the boundaries are at or near "cat-whisker" contacts. The point-contact type was first developed; it is noisier and less stable because of inherent positive feedback. Stable operation is obtained by introducing some external positive resistance in series with one of the electrodes to counteract the effects of the internal negative resistance. Manufacturers suggest from 500 to 1000 ohms. It is well to use the same value of resistance that will be used eventually in the circuit application. The junction type, which is more likely to find use in oscillator and amplifier applications, is inherently stable.

In both types, the input as well as the output resistance can be relatively low. Because of this, it is important to measure the coefficients for both the forward and reverse directions. Also because of the interdependence of the input and output circuits, it is desirable to reduce the base-to-emitter voltage to zero or to open the base connection before operating the coefficient switch of the bridge; this will avoid a possible transient which may require several seconds to resume equilibrium conditions.

Because the resistance of the test-signal sources (e_1 and e_2 in Figure 2) can be comparable to the transistor resistance, the next paragraph is important.

CORRECTIONS DUE TO SOURCE RESISTANCE

The sources of test signal (see Figure 2) are e_1 controlled by the MULTIPLY BY switch and e_2 controlled by the DIVIDE BY switch. The resistance of each test signal source depends on the switch setting (see Table II on page 10).

The resistance of the test signal source controlled by the DIVIDE BY switch (e_1) is significant only when measuring the input or the output resistance of the trans-

TABLE II

RESISTANCE OF VOLTAGE SOURCES

RESISTANCE AT e_1 ("MULTIPLY BY" SWITCH)	SWITCH SETTING	RESISTANCE AT e_2 ("DIVIDE BY" SWITCH)
1 ohm	10^2 to 10^5	1 ohm
9.3 ohms	10	9.3 ohms
27.2 ohms	1	27.2 ohms

ducer (coefficient switch at PLATE RESISTANCE). The error due to this source resistance is always less than one percent if one ohm is subtracted from the indicated value ($r = r' - 1\Omega$).

The resistance (r_e) of the test signal source controlled by the MULTIPLY BY switch is significant only when the coefficient switch is at MUTUAL CONDUCTANCE or at voltage AMPLIFICATION FACTOR. If the input resistance (r) of the device under measurement is sufficiently small, the source resistance (r_e) and the input resistance (r) provide voltage division that effectively reduces e_1. The correct value of transconductance or of voltage amplification factor is then the measured value multiplied by the factor $(1 + \frac{r_e}{r})$. This factor is normally negligible in vacuum-tube measurements and rarely exceeds 1.02 in transistor measurements.

6.0 GENERAL NETWORK CONSIDERATIONS

The transducer of Figure 1 was considered under Section 2.0 and equations which defined conductance parameters were given. These are the nodal equations adopted by the Institute of Radio Engineers in standardizing methods[1] for testing tubes. When a picture of the equivalent network of a transducer is sought, the nodal equations are best expressed by a two-generator network as shown in Figure 6. The Type 561-D Bridge measures the reciprocal of g_{11} (r_{in}), the direct value of g_{12} (reverse transfer conductance), the direct value of g_{21} (forward transconductance) and the reciprocal of g_{22} (r_{out}).

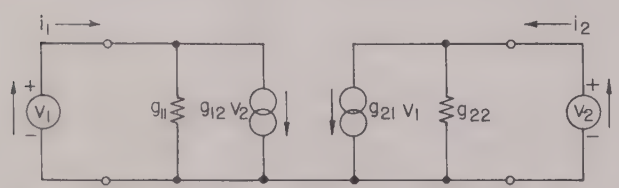


Figure 6. Two-generator nodal-derived equivalent network.

The parameters of the nodal equations can be transformed to new parameters that are depicted by a one-generator π network as shown in Figure 7.

[1] "Standards on Electron Tubes: Methods of Testing", Proceedings of the I. R. E., Volume 38, Numbers 8 and 9, August and September, 1950.

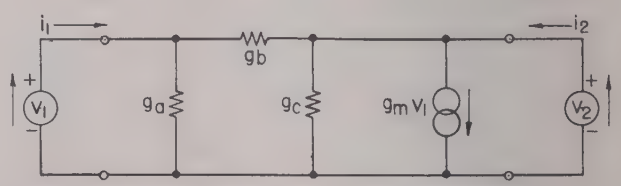


Figure 7. One-generator nodal-derived equivalent network.

The conductance values are related to the nodal-derived two-generator parameters and hence to the values obtained with a Type 561-D Bridge, as follows:

$$g_a = g_{11} + g_{12} \qquad g_c = g_{22} + g_{12}$$

$$g_b = -g_{12} \qquad g_m = g_{21} - g_{12}$$

When the transducer of Figure 1 is measured under the assumed condition of open-circuit terminations rather than short-circuit terminations, the preferred equations for expressing the inter-relation between the voltages and currents are of the loop (mesh) form and the resultant parameters are best expressed as impedances for the general case, resistances for our specific consideration of low frequency applications. The two equations that completely characterize the transducer are then:

$$v_1 = r_{11}\, i_1 + r_{12}\, i_2$$

$$v_2 = r_{22}\, i_2 + r_{21}\, i_1$$

The resistance parameters are depicted by a loop-derived 2-generator equivalent network as shown in Figure 8. Here, r_{11} and r_{22} are the input and output resistances measured under open-circuit termination condition. These values differ in the termination condition from the values r_{in} and r_{out} normally obtained on the Type 561-D Bridge. However, the r_{11} and r_{22} parameters of a transistor, for example, can be obtained directly on the bridge if care is taken to provide the correct d-c bias condition through an impedance that sufficiently simulates an open-circuit at the measuring frequency (1000 cycles), and if great care is taken to effectively shield this open-circuit or high impedance circuit in order to prevent it from picking up signal voltage. One method of doing this is to feed the biasing current through the plate circuit of a shielded pentode. Another method involves the use of a shielded choke coil. It is usually simpler to make the measurements in the manner described in Section 4 and transform the conductance parameters of the nodal-derived equivalent network to the loop-derived parameters as follows:

Nodal	Loop
$g_{11} = r_{22} \div \Delta r$	$r_{11} = g_{22} \div \Delta g$
$g_{12} = -r_{12} \div \Delta r$	$r_{12} = -g_{12} \div \Delta g$
$g_{21} = -r_{21} \div \Delta r$	$r_{21} = -g_{21} \div \Delta g$
$g_{22} = r_{11} \div \Delta r$	$r_{22} = g_{11} \div \Delta g$
$\Delta r = r_{11}\, r_{22} - r_{12}\, r_{21}$	$\Delta g = g_{11}\, g_{22} - g_{12}\, g_{21}$

In performing the transformations, it is important to be careful of signs.

The loop equations can also be shown as a one-generator equivalent network and this is the form seen in much of the transistor literature (Figure 9). The subscripts given in the figure are for a transistor connected for the common-base condition. The one-generator loop derived network parameters are related to the two generator loop-derived network parameters by the following simple equations:

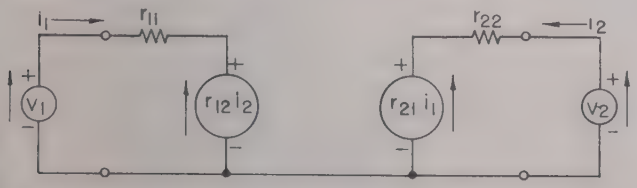


Figure 8. Two-generator loop-derived equivalent network.

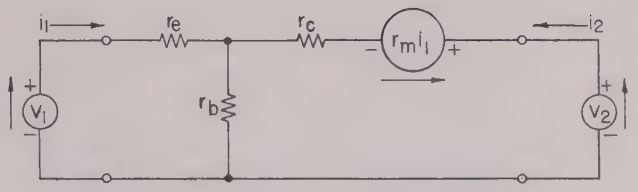


Figure 9. One-generator loop-derived equivalent network.

$$r_e = r_{11} - r_{12} \qquad r_c = r_{22} - r_{12}$$

$$r_b = r_{12} \qquad r_m = r_{21} - r_{12}$$

While, in transistor applications, the coefficients that correspond to the two-generator nodal-derived equivalent network will perhaps be the most useful for design applications, it may be desirable to be able to transform quickly from one arrangement to another. The data in Table III simplify conversion[2] from one form of network to another, whether it be one- or two-generator, nodal or loop, common-emitter, -base or -collector connected. When transforming from nodal to loop or vice-versa, the nodal-loop equations above are to be used.

The α_{ce} of the table is the current amplification factor often referred to in transistor literature. It is very close to unity for junction-type transistors and usually between 0.2 and 3 for the point-contact type.

The power-amplification factor, ϕ, is defined by Giacoletto[2] as "the maximum power amplification in a given direction when the transfer impedance or the transfer admittance in the opposite direction is zero." This factor should be very useful as an index of transistor performance.

COMMENTS ON TABLE III

The parameters are expressed in the table as admittances (y) rather than conductances (g) and as impedances (z) rather than resistances (r) since the table can be useful in considering the more general case of transistor parameters at any frequency.

For the 2-generator networks, the third subscript[2] refers to the common electrode. For the one-generator networks, the pre-subscript refers to the common electrode.

When transforming from one common-electrode circuit to another, not only do the parameters have new values and possibly new signs but the new effective applied terminal voltages may be of different value and sign as indicated in Table III.

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[2] L. J. Giocoletto, R.C.A. Review, Volume 14, No. 1, March 1953, pp. 28-46.

TABLE III

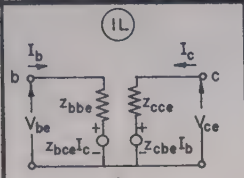
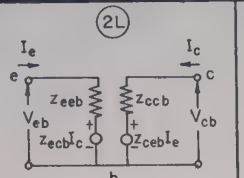
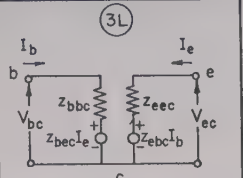
NODAL-DERIVED EQUIVALENT CIRCUITS

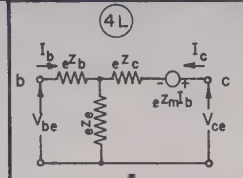
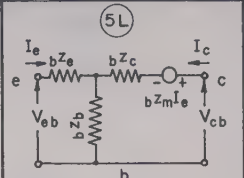
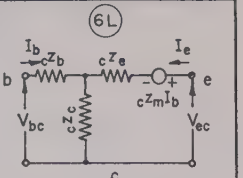
	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
EQUATIONS	$I_b = y_{bbe} V_{be} + y_{bce} V_{ce}$ $I_c = y_{cbe} V_{be} + y_{cce} V_{ce}$	$I_e = y_{eeb} V_{eb} + y_{ecb} V_{cb}$ $I_c = y_{ceb} V_{eb} + y_{ccb} V_{cb}$	$I_b = y_{bbc} V_{bc} + y_{bec} V_{ec}$ $I_e = y_{ebc} V_{bc} + y_{eec} V_{ec}$
TWO – GEN.	(1N)	(2N)	(3N)
AMP. FACTORS	FORWARD: $\alpha_{cb} = -\frac{y_{cbe}}{y_{bbe}}$; $\mu_{cb} = -\frac{y_{cbe}}{y_{cce}}$; $\phi_{cb} = \frac{\lvert y_{cbe}\rvert^2}{4 g_{bbe} g_{cce}}$ REVERSE: $\alpha_{bc} = -\frac{y_{bce}}{y_{cce}}$; $\mu_{bc} = -\frac{y_{bce}}{y_{bbe}}$; $\phi_{bc} = \frac{\lvert y_{bce}\rvert^2}{4 g_{bbe} g_{cce}}$	FORWARD: $\alpha_{ce} = -\frac{y_{ceb}}{y_{eeb}}$; $\mu_{ce} = -\frac{y_{ceb}}{y_{ccb}}$; $\phi_{ce} = \frac{\lvert y_{ceb}\rvert^2}{4 g_{eeb} g_{ccb}}$ REVERSE: $\alpha_{ec} = -\frac{y_{ecb}}{y_{ccb}}$; $\mu_{ec} = -\frac{y_{ecb}}{y_{eeb}}$; $\phi_{ec} = \frac{\lvert y_{ecb}\rvert^2}{4 g_{eeb} g_{ccb}}$	FORWARD: $\alpha_{eb} = -\frac{y_{ebc}}{y_{bbc}}$; $\mu_{eb} = -\frac{y_{ebc}}{y_{eec}}$; $\phi_{eb} = \frac{\lvert y_{ebc}\rvert^2}{4 g_{bbc} g_{eec}}$ REVERSE: $\alpha_{be} = -\frac{y_{bec}}{y_{eec}}$; $\mu_{be} = -\frac{y_{bec}}{y_{bbc}}$; $\phi_{be} = \frac{\lvert y_{bec}\rvert^2}{4 g_{bbc} g_{eec}}$
TRANSFORMATION EQUATIONS	(4N) → (1N) $y_{bbe} = {}_e y_{be} + {}_e y_{bc}$ $y_{bce} = -{}_e y_{bc}$ $y_{cbe} = {}_e y_m - {}_e y_{bc}$ $y_{cce} = {}_e y_{ce} + {}_e y_{bc}$	(5N) → (2N) $y_{eeb} = {}_b y_{eb} + {}_b y_{ec}$ $y_{ecb} = -{}_b y_{ec}$ $y_{ceb} = {}_b y_m - {}_b y_{ec}$ $y_{ccb} = {}_b y_{cb} + {}_b y_{ec}$	(6N) → (3N) $y_{bbc} = {}_c y_{bc} + {}_c y_{be}$ $y_{bec} = -{}_c y_{be}$ $y_{ebc} = {}_c y_m - {}_c y_{be}$ $y_{eec} = {}_c y_{ec} + {}_c y_{be}$
	(2N) → (1N) $V_{be} = -V_{eb}$; $V_{ce} = V_{cb} - V_{eb}$ $y_{bbe} = y_{eeb} + y_{ecb} + y_{ceb} + y_{ccb}$ $y_{bce} = -(y_{ccb} + y_{ecb})$ $y_{cbe} = -(y_{ccb} + y_{ceb})$ $y_{cce} = y_{ccb}$	(3N) → (2N) $V_{eb} = V_{ec} - V_{bc}$; $V_{cb} = -V_{bc}$ $y_{eeb} = y_{eec}$ $y_{ecb} = -(y_{eec} + y_{ebc})$ $y_{ceb} = -(y_{eec} + y_{bec})$ $y_{ccb} = y_{bbc} + y_{bec} + y_{ebc} + y_{eec}$	(1N) → (3N) $V_{bc} = V_{be} - V_{ce}$; $V_{ec} = -V_{ce}$ $y_{bbc} = y_{bbe}$ $y_{bec} = -(y_{bbe} + y_{bce})$ $y_{ebc} = -(y_{bbe} + y_{cbe})$ $y_{eec} = y_{bbe} + y_{cbe} + y_{bce} + y_{cce}$
	(3N) → (1N) $V_{be} = V_{bc} - V_{ec}$; $V_{ce} = -V_{ec}$ $y_{bbe} = y_{bbc}$ $y_{bce} = -(y_{bbc} + y_{bec})$ $y_{cbe} = -(y_{bbc} + y_{ebc})$ $y_{cce} = y_{bbc} + y_{bec} + y_{ebc} + y_{eec}$	(1N) → (2N) $V_{eb} = -V_{be}$; $V_{cb} = V_{ce} - V_{be}$ $y_{eeb} = y_{bbe} + y_{cbe} + y_{bce} + y_{cce}$ $y_{ecb} = -(y_{cce} + y_{bce})$ $y_{ceb} = -(y_{cce} + y_{cbe})$ $y_{ccb} = y_{cce}$	(2N) → (3N) $V_{bc} = -V_{cb}$; $V_{ec} = V_{eb} - V_{cb}$ $y_{bbc} = y_{eeb} + y_{ecb} + y_{ceb} + y_{ccb}$ $y_{bec} = -(y_{eeb} + y_{ceb})$ $y_{ebc} = -(y_{eeb} + y_{ecb})$ $y_{eec} = y_{eeb}$

NODAL-DERIVED EQUIVALENT CIRCUITS

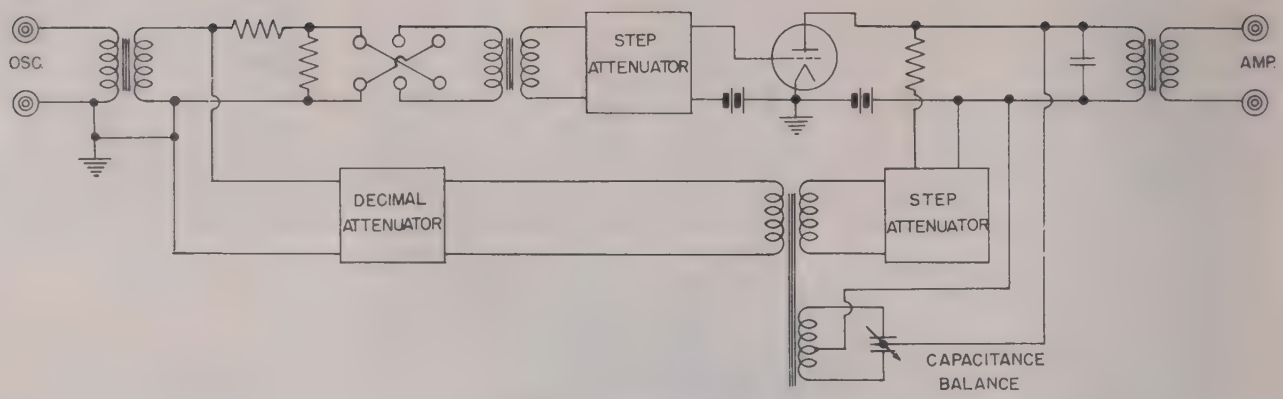
	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
EQUATIONS	$I_b = ({}_e y_{be} + {}_e y_{bc}) V_{be} - {}_e y_{bc} V_{ce}$ $I_c = ({}_e y_m - {}_e y_{bc}) V_{be} + ({}_e y_{ce} + {}_e y_{bc}) V_{ce}$	$I_e = ({}_b y_{eb} + {}_b y_{ec}) V_{eb} - {}_b y_{ec} V_{cb}$ $I_c = ({}_b y_m - {}_b y_{ec}) V_{eb} + ({}_b y_{cb} + {}_b y_{ec}) V_{cb}$	$I_b = ({}_c y_{bc} + {}_c y_{be}) V_{bc} - {}_c y_{be} V_{ec}$ $I_e = ({}_c y_m - {}_c y_{be}) V_{bc} + ({}_c y_{ec} + {}_c y_{be}) V_{ec}$
ONE – GEN.	(4N)	(5N)	(6N)
AMP. FACTORS	FORWARD: $\alpha_{cb} = -\frac{{}_e y_m - {}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$; $\mu_{cb} = -\frac{{}_e y_m - {}_e y_{bc}}{{}_e y_{ce} + {}_e y_{bc}}$; $\phi_{cb} = \frac{\lvert {}_e y_m - {}_e y_{bc}\rvert^2}{4({}_e g_{be} + {}_e g_{bc})({}_e g_{ce} + {}_e g_{bc})}$; $\phi_{bc} = \frac{\lvert {}_e y_{bc}\rvert^2}{4({}_e g_{be} + {}_e g_{bc})({}_e g_{ce} + {}_e g_{bc})}$ REVERSE: $\alpha_{bc} = +\frac{{}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$; $\mu_{bc} = +\frac{{}_e y_{bc}}{{}_e y_{be} + {}_e y_{bc}}$	FORWARD: $\alpha_{ce} = -\frac{{}_b y_m - {}_b y_{ec}}{{}_b y_{eb} + {}_b y_{ec}}$; $\mu_{ce} = -\frac{{}_b y_m - {}_b y_{ec}}{{}_b y_{cb} + {}_b y_{ec}}$; $\phi_{ce} = \frac{\lvert {}_b y_m - {}_b y_{ec}\rvert^2}{4({}_b g_{eb} + {}_b g_{ec})({}_b g_{cb} + {}_b g_{ec})}$; $\phi_{ec} = \frac{\lvert {}_b y_{ec}\rvert^2}{4({}_b g_{eb} + {}_b g_{ec})({}_b g_{cb} + {}_b g_{ec})}$ REVERSE: $\alpha_{ec} = +\frac{{}_b y_{ec}}{{}_b y_{cb} + {}_b y_{ec}}$; $\mu_{ec} = +\frac{{}_b y_{ec}}{{}_b y_{eb} + {}_b y_{ec}}$	FORWARD: $\alpha_{eb} = -\frac{{}_c y_m - {}_c y_{be}}{{}_c y_{bc} + {}_c y_{be}}$; $\mu_{eb} = -\frac{{}_c y_m - {}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$; $\phi_{eb} = \frac{\lvert {}_c y_m - {}_c y_{be}\rvert^2}{4({}_c g_{bc} + {}_c g_{be})({}_c g_{ec} + {}_c g_{be})}$; $\phi_{be} = \frac{\lvert {}_c y_{be}\rvert^2}{4({}_c g_{bc} + {}_c g_{be})({}_c g_{ec} + {}_c g_{be})}$ REVERSE: $\alpha_{be} = +\frac{{}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$; $\mu_{be} = +\frac{{}_c y_{be}}{{}_c y_{ec} + {}_c y_{be}}$
TRANSFORMATION EQUATIONS	(1N) → (4N) ${}_e y_{be} = y_{bbe} + y_{bce}$ ${}_e y_{bc} = -y_{bce}$ ${}_e y_{ce} = y_{cce} + y_{bce}$ ${}_e y_m = y_{cbe} - y_{bce}$	(2N) → (5N) ${}_b y_{eb} = y_{eeb} + y_{ecb}$ ${}_b y_{ec} = -y_{ecb}$ ${}_b y_{cb} = y_{ccb} + y_{ecb}$ ${}_b y_m = y_{ceb} - y_{ecb}$	(3N) → (6N) ${}_c y_{bc} = y_{bbc} + y_{bec}$ ${}_c y_{be} = -y_{bec}$ ${}_c y_{ec} = y_{eec} + y_{bec}$ ${}_c y_m = y_{ebc} - y_{bec}$
	(5N) → (4N) $V_{be} = -V_{eb}$; $V_{ce} = V_{cb} - V_{eb}$ ${}_e y_{be} = {}_b y_{eb} + {}_b y_m$ ${}_e y_{bc} = {}_b y_{cb}$ ${}_e y_{ce} = {}_b y_{ec}$ ${}_e y_m = -{}_b y_m$	(6N) → (5N) $V_{eb} = V_{ec} - V_{bc}$; $V_{cb} = -V_{bc}$ ${}_b y_{eb} = {}_c y_{be} - {}_c y_m$ ${}_b y_{ec} = {}_c y_{ec} + {}_c y_m$ ${}_b y_{cb} = {}_c y_{bc}$ ${}_b y_m = {}_c y_m$	(4N) → (6N) $V_{bc} = V_{be} - V_{ce}$; $V_{ec} = -V_{ce}$ ${}_c y_{bc} = {}_e y_{bc}$ ${}_c y_{be} = {}_e y_{be}$ ${}_c y_{ec} = {}_e y_{ce} + {}_e y_m$ ${}_c y_m = -{}_e y_m$
	(6N) → (4N) $V_{be} = V_{bc} - V_{ec}$; $V_{ce} = -V_{ec}$ ${}_e y_{be} = {}_c y_{be}$ ${}_e y_{bc} = {}_c y_{bc}$ ${}_e y_{ce} = {}_c y_{ec} + {}_c y_m$ ${}_e y_m = -{}_c y_m$	(4N) → (5N) $V_{eb} = -V_{be}$; $V_{cb} = V_{ce} - V_{be}$ ${}_b y_{eb} = {}_e y_{be} + {}_e y_m$ ${}_b y_{ec} = {}_e y_{ce}$ ${}_b y_{cb} = {}_e y_{bc}$ ${}_b y_m = -{}_e y_m$	(5N) → (6N) $V_{bc} = -V_{cb}$; $V_{ec} = V_{eb} - V_{cb}$ ${}_c y_{bc} = {}_b y_{cb}$ ${}_c y_{be} = {}_b y_{eb} + {}_b y_m$ ${}_c y_{ec} = {}_b y_{ec} - {}_b y_m$ ${}_c y_m = {}_b y_m$

LOOP-DERIVED EQUIVALENT CIRCUITS

	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
EQUATIONS	$V_{be}=z_{bbe}\,I_b+z_{bce}\,I_c$ $V_{ce}=z_{cbe}\,I_b+z_{cce}\,I_c$	$V_{eb}=z_{eeb}\,I_e+z_{ecb}I_c$ $V_{cb}=z_{ceb}\,I_e+z_{ccb}I_c$	$V_{bc}=z_{bbc}\,I_b+z_{bec}\,I_e$ $V_{ec}=z_{ebc}\,I_b+z_{eec}\,I_e$
TWO-GEN.	(1L)  e	(2L)  b	(3L)  c
AMP. FACTORS	FORWARD: $\alpha_{cb}=+\frac{z_{cbe}}{z_{cce}}$; $\mu_{cb}=+\frac{z_{cbe}}{z_{bbe}}$; $\phi_{cb}=\frac{\lvert z_{cbe}\rvert^2}{4r_{bbe}\,r_{cce}}$ REVERSE: $\alpha_{bc}=+\frac{z_{bce}}{z_{bbe}}$; $\mu_{bc}=+\frac{z_{bce}}{z_{cce}}$; $\phi_{bc}=\frac{\lvert z_{bce}\rvert^2}{4r_{bbe}\,r_{cce}}$	FORWARD: $\alpha_{ce}=+\frac{z_{ceb}}{z_{ccb}}$; $\mu_{ce}=+\frac{z_{ceb}}{z_{eeb}}$; $\phi_{ce}=\frac{\lvert z_{ceb}\rvert^2}{4r_{eeb}\,r_{ccb}}$ REVERSE: $\alpha_{ec}=+\frac{z_{ecb}}{z_{eeb}}$; $\mu_{ec}=+\frac{z_{ecb}}{z_{ccb}}$; $\phi_{ec}=\frac{\lvert z_{ecb}\rvert^2}{4r_{eeb}\,r_{ccb}}$	FORWARD: $\alpha_{eb}=+\frac{z_{ebc}}{z_{eec}}$; $\mu_{eb}=+\frac{z_{ebc}}{z_{bbc}}$; $\phi_{eb}=\frac{\lvert z_{ebc}\rvert^2}{4r_{bbc}\,r_{eec}}$ REVERSE: $\alpha_{be}=+\frac{z_{bec}}{z_{bbc}}$; $\mu_{be}=+\frac{z_{bec}}{z_{eec}}$; $\phi_{be}=\frac{\lvert z_{bec}\rvert^2}{4r_{bbc}\,r_{eec}}$
TRANSFORMATION EQUATIONS	(4L)→(1L) $z_{bbe}={}_e z_b+{}_e z_e$ $z_{bce}={}_e z_e$ $z_{cbe}={}_e z_m+{}_e z_e$ $z_{cce}={}_e z_c+{}_e z_e$	(5L)→(2L) $z_{eeb}={}_b z_e+{}_b z_b$ $z_{ecb}={}_b z_b$ $z_{ceb}={}_b z_m+{}_b z_b$ $z_{ccb}={}_b z_c+{}_b z_b$	(6L)→(3L) $z_{bbc}={}_c z_b+{}_c z_c$ $z_{bec}={}_c z_c$ $z_{ebc}={}_c z_m+{}_c z_c$ $z_{eec}={}_c z_e+{}_c z_c$
	(2L)→(1L) $V_{be}=-V_{eb}$; $V_{ce}=V_{cb}-V_{eb}$ $z_{bbe}=z_{eeb}$ $z_{bce}=z_{eeb}-z_{ecb}$ $z_{cbe}=z_{eeb}-z_{ceb}$ $z_{cce}=z_{eeb}-z_{ecb}-z_{ceb}+z_{ccb}$	(3L)→(2L) $V_{eb}=V_{ec}-V_{bc}$; $V_{cb}=-V_{bc}$ $z_{eeb}=z_{bbc}-z_{bec}-z_{ebc}-z_{eec}$ $z_{ecb}=z_{bbc}-z_{ebc}$ $z_{ceb}=z_{bbc}-z_{bec}$ $z_{ccb}=z_{bbc}$	(1L)→(3L) $V_{bc}=V_{be}-V_{ce}$; $V_{ec}=-V_{ce}$ $z_{bbc}=z_{bbe}-z_{bce}-z_{cbe}+z_{cce}$ $z_{bec}=z_{cce}-z_{bce}$ $z_{ebc}=z_{cce}-z_{cbe}$ $z_{eec}=z_{cce}$
	(3L)→(1L) $V_{be}=V_{bc}-V_{ec}$; $V_{ce}=-V_{ec}$ $z_{bbe}=z_{bbc}-z_{ebc}-z_{bec}+z_{eec}$ $z_{bce}=z_{eec}-z_{bec}$ $z_{cbe}=z_{eec}-z_{ebc}$ $z_{cce}=z_{eec}$	(1L)→(2L) $V_{eb}=-V_{be}$; $V_{cb}=V_{ce}-V_{be}$ $z_{eeb}=z_{bbe}$ $z_{ecb}=z_{bbe}-z_{bce}$ $z_{ceb}=z_{bbe}-z_{cbe}$ $z_{ccb}=z_{bbe}-z_{bce}-z_{cbe}+z_{cce}$	(2L)→(3L) $V_{bc}=-V_{cb}$; $V_{ec}=V_{eb}-V_{cb}$ $z_{bbc}=z_{ccb}$ $z_{bec}=z_{ccb}-z_{ceb}$ $z_{ebc}=z_{ccb}-z_{ecb}$ $z_{eec}=z_{eeb}-z_{ecb}-z_{ceb}+z_{ccb}$

	COMMON EMITTER	COMMON BASE	COMMON COLLECTOR
EQUATIONS	$V_{be}=({}_e z_b+{}_e z_e)I_b+{}_e z_e\,I_c$ $V_{ce}=({}_e z_m+{}_e z_e)I_b+({}_e z_c+{}_e z_e)I_c$	$V_{eb}=({}_b z_e+{}_b z_b)I_e+{}_b z_b\,I_c$ $V_{cb}=({}_b z_m+{}_b z_b)I_e+({}_b z_c+{}_b z_b)I_c$	$V_{bc}=({}_c z_b+{}_c z_c)I_b+{}_c z_c\,I_e$ $V_{ec}=({}_c z_m+{}_c z_c)I_b+({}_c z_e+{}_c z_c)I_e$
ONE-GEN.	(4L)  a	(5L)  b	(6L)  c
AMP. FACTORS	FORWARD: $\alpha_{cb}=\frac{{}_e z_m+{}_e z_e}{{}_e z_c+{}_e z_e}$; $\mu_{cb}=\frac{{}_e z_m+{}_e z_e}{{}_e z_b+{}_e z_e}$; $\phi_{cb}=\frac{\lvert {}_e z_m+{}_e z_e\rvert^2}{4({}_e r_b+{}_e r_e)({}_e r_c+{}_e r_e)}$ REVERSE: $\alpha_{bc}=\frac{{}_e z_e}{{}_e z_b+{}_e z_e}$; $\mu_{bc}=\frac{{}_e z_e}{{}_e z_c+{}_e z_e}$; $\phi_{bc}=\frac{\lvert {}_e z_e\rvert^2}{4({}_e r_b+{}_e r_e)({}_e r_c+{}_e r_e)}$	FORWARD: $\alpha_{ce}=\frac{{}_b z_m+{}_b z_b}{{}_b z_c+{}_b z_b}$; $\mu_{ce}=\frac{{}_b z_m+{}_b z_b}{{}_b z_e+{}_b z_b}$; $\phi_{ce}=\frac{\lvert {}_b z_m+{}_b z_b\rvert^2}{4({}_b r_e+{}_b r_b)({}_b r_c+{}_b r_b)}$ REVERSE: $\alpha_{ec}=\frac{{}_b z_b}{{}_b z_c+{}_b z_b}$; $\mu_{ec}=\frac{{}_b z_b}{{}_b z_e+{}_b z_b}$; $\phi_{ec}=\frac{\lvert {}_b z_b\rvert^2}{4({}_b r_e+{}_b r_b)({}_b r_c+{}_b r_b)}$	FORWARD: $\alpha_{eb}=\frac{{}_c z_m+{}_c z_c}{{}_c z_e+{}_c z_c}$; $\mu_{eb}=\frac{{}_c z_m+{}_c z_c}{{}_c z_b+{}_c z_c}$; $\phi_{eb}=\frac{\lvert {}_c z_m+{}_c z_c\rvert^2}{4({}_c r_b+{}_c r_c)({}_c r_e+{}_c r_c)}$ REVERSE: $\alpha_{be}=\frac{{}_c z_c}{{}_c z_e+{}_c z_c}$; $\mu_{be}=\frac{{}_c z_c}{{}_c z_b+{}_c z_c}$; $\phi_{be}=\frac{\lvert {}_c z_c\rvert^2}{4({}_c r_b+{}_c r_c)({}_c r_e+{}_c r_c)}$
TRANSFORMATION EQUATIONS	(1L)→(4L) ${}_e z_b=z_{bbe}-z_{bce}$ ${}_e z_e=z_{bce}$ ${}_e z_c=z_{cce}-z_{bce}$ ${}_e z_m=z_{cbe}-z_{bce}$	(2L)→(5L) ${}_b z_e=z_{eeb}-z_{ecb}$ ${}_b z_b=z_{ecb}$ ${}_b z_c=z_{ccb}-z_{ecb}$ ${}_b z_m=z_{ceb}-z_{ecb}$	(3L)→(6L) ${}_c z_b=z_{bbc}-z_{bec}$ ${}_c z_c=z_{bec}$ ${}_c z_e=z_{eec}-z_{bec}$ ${}_c z_m=z_{ebc}-z_{bec}$
	(5L)←(4L) $V_{be}=-V_{eb}$; $V_{ce}=V_{cb}-V_{eb}$ ${}_e z_b={}_b z_b$ ${}_e z_e={}_b z_e$ ${}_e z_c={}_b z_c-{}_b z_m$ ${}_e z_m=-{}_b z_m$	(6L)→(5L) $V_{eb}=V_{ec}-V_{bc}$; $V_{cb}=-V_{bc}$ ${}_b z_e={}_c z_e$ ${}_b z_b={}_c z_b-{}_c z_m$ ${}_b z_c={}_c z_c+{}_c z_m$ ${}_b z_m={}_c z_m$	(4L)→(6L) $V_{bc}=V_{be}-V_{ce}$; $V_{ec}=-V_{ce}$ ${}_c z_b={}_e z_b-{}_e z_m$ ${}_c z_c={}_e z_c$ ${}_c z_e={}_e z_e$ ${}_c z_m=-{}_e z_m$
	(6L)→(4L) $V_{be}=V_{bc}-V_{ec}$; $V_{ce}=-V_{ec}$ ${}_e z_b={}_c z_b-{}_c z_m$ ${}_e z_e={}_c z_e$ ${}_e z_c={}_c z_c$ ${}_e z_m=-{}_c z_m$	(4L)→(5L) $V_{eb}=-V_{be}$; $V_{cb}=V_{ce}-V_{be}$ ${}_b z_e={}_e z_e$ ${}_b z_b={}_e z_b$ ${}_b z_c={}_e z_c-{}_e z_m$ ${}_b z_m=-{}_e z_m$	(5L)→(6L) $V_{bc}=-V_{cb}$; $V_{ec}=V_{eb}-V_{cb}$ ${}_c z_b={}_b z_b+{}_b z_m$ ${}_c z_c={}_b z_c-{}_b z_m$ ${}_c z_e={}_b z_e$ ${}_c z_m={}_b z_m$

Courtesy of "R.C.A. Review".



ELEMENTARY SCHEMATIC DIAGRAM

PARTS LIST

RESISTORS

R-1	=	60	Ohms ±1/4%	561-306
R-2	=	545.5	Ohms ±1/4%	561-306
R-3	=	100 K	Ohms ±1/4%	IRC Type WW-1
R-4	=	33	Ohms ±10%	REC-20BF
R-5	=	33	Ohms ±10%	REC-20BF
R-6	=	33	Ohms ±10%	REC-20BF
R-7	=	33	Ohms ±10%	REC-20BF
R-8	=	33	Ohms ±10%	REC-20BF
R-9	=	33	Ohms ±10%	REC-20BF
R-10	=	33	Ohms ±10%	REC-20BF
R-11	=	33	Ohms ±10%	REC-20BF
R-12	=	33	Ohms ±10%	REC-20BF
R-13	=	33	Ohms ±10%	REC-20BF
R-14	=	33	Ohms ±10%	REC-20BF
R-15	=	33	Ohms ±10%	REC-20BF
R-16	=	33	Ohms ±10%	REC-20BF
R-17	=	33	Ohms ±10%	REC-20BF
R-18	=	33	Ohms ±10%	REC-20BF
R-19	=	33	Ohms ±10%	REC-20BF
R-20	=	33	Ohms ±10%	REC-20BF
R-21	=	33	Ohms ±10%	REC-20BF
R-22	=	33	Ohms ±10%	REC-20BF
R-23	=	33	Ohms ±10%	REC-20BF
R-24	=	33	Ohms ±10%	REC-20BF
R-25	=	33	Ohms ±10%	REC-20BF

CONDENSERS

C-1 = 0.02 μf ±5% COM-50B
C-2 = 561-330

CORD JACKS

J-1 to J-9 Inclusive 774-314

FILTER

RC-1 = 561-380

TRANSFORMERS

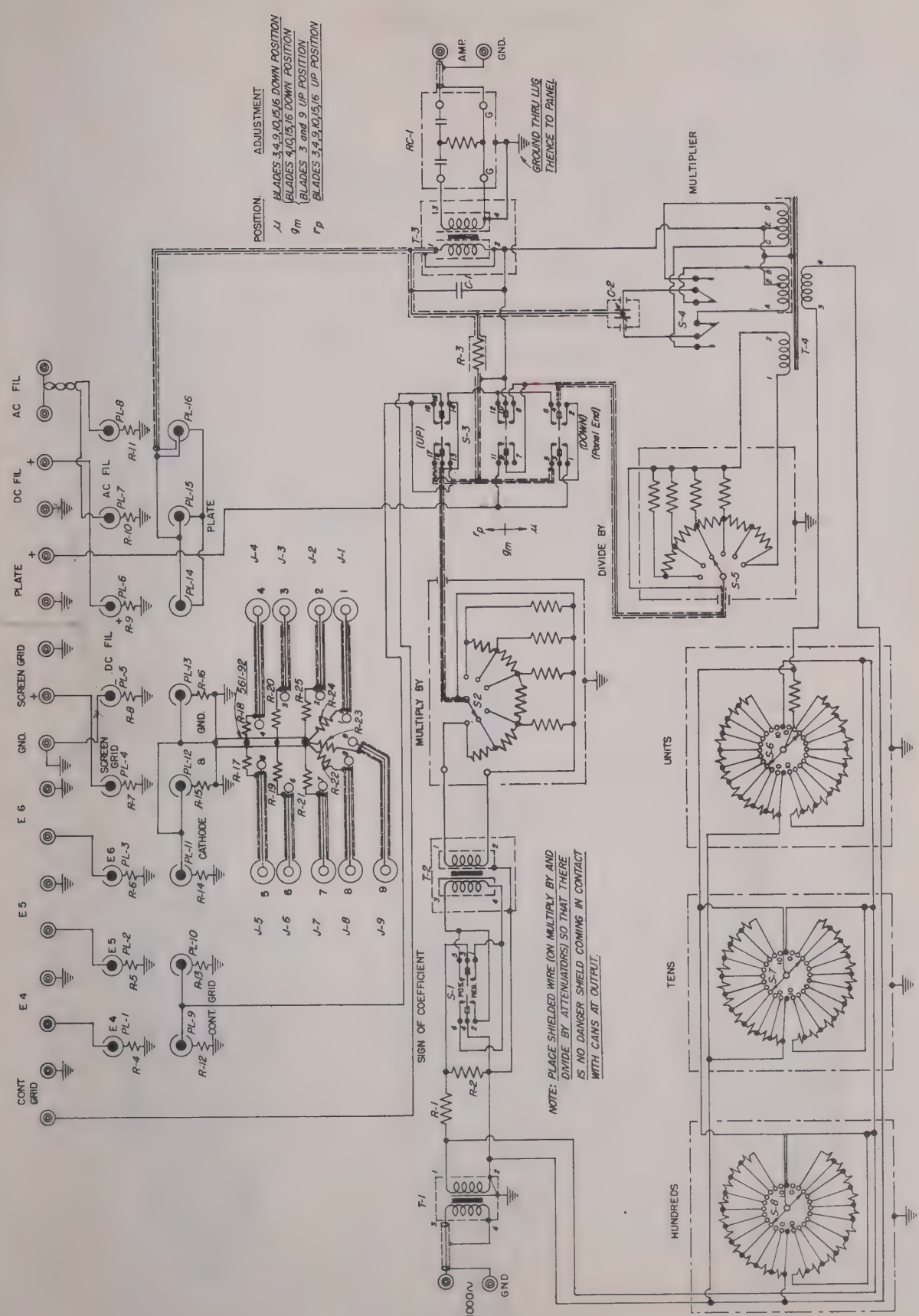
T-1 = 561-390
T-2 = 561-35
T-3 = 561-34
T-4 = 561-36

SWITCHES

S-1 = 2 P.D.T. 339-401
S-2 = 561-318
S-3 = 6 P.D.T. 339-C
S-4 = SWP-933
S-5 = 561-318
S-6 = 561-338
S-7 = 561-337
S-8 = 561-336

PANEL PLUGS

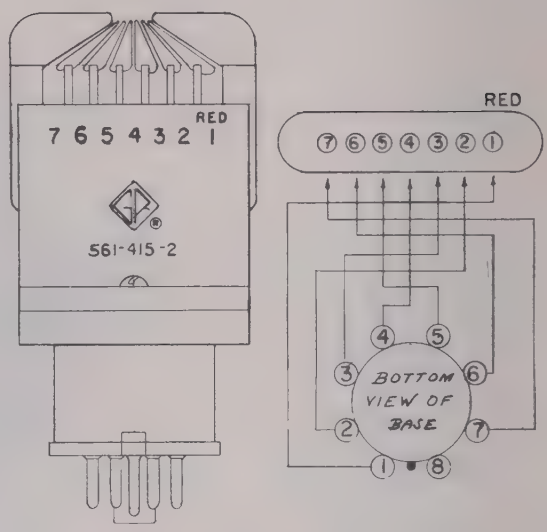
PL-1 to PL-16 Inclusive 774-301



WIRING DIAGRAM FOR TYPE 561-D VACUUM-TUBE BRIDGE

TYPE 561-415-2 SUBMINIATURE TUBE TEST ADAPTER

The Type 561-415-2 Tube Adapter is designed to facilitate the testing of flat-press subminiature tubes with seven or less leads in the same plane having a minimum length of 1-1/2 inches. The adapter is made up of a comb for aligning the tube leads, mounted above a polystyrene spring contact housing, which in turn terminates in a standard octal base. The adapter wiring arrangement between the subminiature tube lead contacts and the octal base pins is shown in the figure.



Tube insertion is accomplished simply, as follows:

Step A: Insert the tube leads between the teeth of the adapter comb at a point near the press, or the base of the tube, where the leads are more rigid; the tube should be held about a right angle to the comb with the tip of the tube away from the operator. (See Figure A)

Step B: Draw the tube up and back from the adapter, combing the leads through the teeth of the comb, at the same time bring the tube to a vertical position until the ends of the leads fall into the channels above the lead contact openings. (See Figure B)

Step C: Push down on the tube until the leads are engaged by the lead contact springs. (See Figure C)

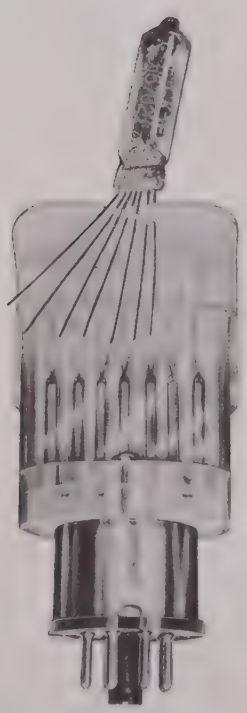


Figure A

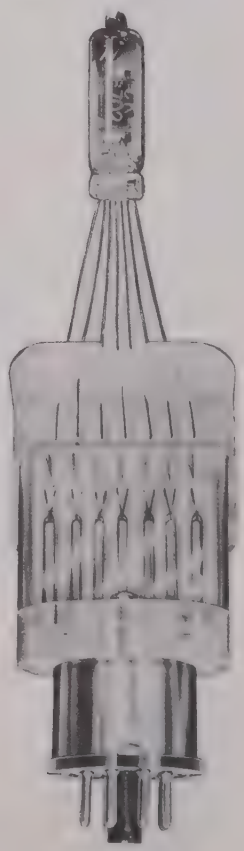


Figure B

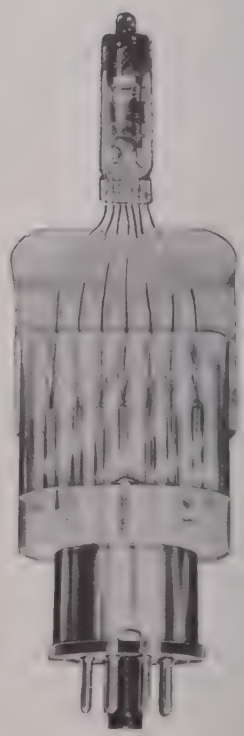


Figure C

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